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F01/7700 0.00-0230207.3

1/77

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The Patent Office

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1. Your reference

2. Patent application number
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27 DEC 2002 0230207.3

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Mecon Ltd
5a Pound Hill
Cambridge CB3 ØAE
UK

~~06934301001~~

Patents ADP number *(if you know it)* CØ8922

If the applicant is a corporate body, give the country/state of its incorporation

Martin Thompson ~~08534521001~~ Mark Harper ~~08534539001~~

4. Title of the invention

Leak Locator

5. Name of your agent *(if you have one)*

Barker Brettel

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

M. Thompson
Mecon Ltd
5a Pound Hill
Cambridge CB3 ØAE

07442494004

Patents ADP number *(if you know it)* CØ8922

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
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Continuation sheets of this form	
Description	12
Claim(s)	—
Abstract	—
Drawing(s)	5

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Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature M. Thompson Date 24.12.2
Mark Caple 24.12.2

12. Name and daytime telephone number of person to contact in the United Kingdom — M. Thompson 01223 355990

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LEAK LOCATOR

The present invention relates to a leak detection / location system for use in pipelines.

In petroleum oil, in water and in gas pipelines there are from time to time leaks of the transported fluid through punctures or cracks in the pipe wall. Such leaks can be of economic and environmental importance and need to be located as quickly as possible. The more accurately they can be located the less disruption there is to the environment and to above ground infrastructure such as roads. There are means available to detect leaks of this nature but none of them is entirely successful in pipelines exceeding 300mm in diameter or in plastic pipes exceeding 400m in length between access points.

A sudden rupture can generate pressure transients that can be detected at each end of the pipe. The timing of these transients can be interpreted to give the location of the leak. However such transient detection means can be thwarted by attenuation in the pressure pulse over distances exceeding 400m. Also smearing of the original signal by dispersion in pipes greater than 300mm in diameter can invalidate interpretation. Dispersion is a physical phenomenon whereby the speed of sound is frequency dependent. As a result the characteristic shape of time varying signals are distorted with increasing distance. Dispersion can be a significant problem in some pipelines over distances over distances exceeding 400m and would deny the benefit of the interpretation of pressure transients. Pressure transients can also arise from other sources than leaks and it is difficult to avoid

false alarms. For these reasons, pressure transient detection is only used in limited application such as process plant.

A leak of fluid from a pipe that is under pressure generates broad-band noise that travels both upstream and downstream along the pipe and the contained fluid. If the noise is detected both upstream and downstream by means of a vibration transducer attached to the pipe then cross-correlation of these signals can often give an indication of the location of the leak. This means is a first stage in detection — indicating there is a leak and giving some indication of the area in which it might be found. However this means is thwarted by attenuation particularly in plastic pipes exceeding typically 400m in length and by dispersion in pipes typically 300mm in diameter. A number of systems utilising vibration transducers in such a method are available from Palmer Environmental Ltd, Gutermann and Primayer Ltd for example.

The acoustic noise from a fluid leak is often transmitted through the surrounding material to the ground surface. The surface noise level is extremely low but there are means of detecting that noise and locating the leak. However the use of surface noise to give a final accurate location of a leak is a second stage location method. In the first stage one needs to know there is a leak to look for and to know roughly the area in which to look, otherwise a search can take a long time. Second stage devices that detect at a single point on the ground surface are known as ground microphones and are available from all the companies mentioned previously. A second stage device that detects along a line rather than at one point is the Magic Carpet manufactured by Stest Ltd.

A first and second stage device for water pipes is available from PII Waterline Ltd sold under the Registered Trade Mark of the 'Sahara Leak' Detection System'. This device consists of a hydrophone tethered to an umbilical cable that connects the hydrophone through the pipe back to the surface through a gland at the insertion point. The device is inserted into a pipeline and drawn along by the water. It drags the umbilical along behind it and listens for acoustic noise from leaks. The noise data is relayed back to the surface via the umbilical cable. The umbilical limits the distance over which this device can be deployed, typically up to half a kilometre. The use of an umbilical may disturb deposits on the pipe wall and so discolour the water – something that Water Companies prefer to avoid.

When distances are greater than a few hundred metres and the pipe diameter is greater than of the order of 300mm it is more effective to detect leaks from the inside of the pipe. Such systems are first and second stage detection devices, determining that there is a leak and locating that leak. The Sahara System is limited in range of operation by the use of an umbilical.

Summary of the Invention

According to the invention there is provided a leak location device comprising a housing shaped and sized such that the device may be introduced into and retrieved from a pipeline through existing fittings and travel with the flow of fluid through the pipeline, the housing accommodating a hydrophone coupled to a memory for recording the

hydrophone output signal together with the time at which the signal is recorde as the device passes through the pipeline, the housing having a resilient outer surface and the device having substantially neutral buoyancy in the fluid passing through the pipeline. The device will determine that there is a leak and locate the position of that leak.

Preferably the housing accommodates a low frequency electromagnetic continuous detector – occasional transmitter (CDOT) for firstly detecting and then recording the time at which the device passes surface low frequency electromagnetic continuous transmitter – continuous detectors (CTCD) placed at the launch and retrieve ends and at intermediate points. When the signal transmitted from the surface is detected by the on-board receiver, the on-board transmitter gives out a reply that is noted by the surface receiver. The on-board recording of the times at which surface transmitters are detected and knowledge of their locations will allow the times at which the device detects leaks to be correlated with distance travelled along the pipe. The detection at the surface of the reply transmitted by the on-board CDOT device gives an indication of the progress of the device through the pipe. When a time passes since last detecting a surface transmitter that substantially exceeds the expected travel time between launch and retrieve points, the on-board transmitter will preferably begin to transmit an alarm signal every few seconds. The alarm will be used to locate the device with a hand held surface low frequency electromagnetic detector if the in-pipe device becomes stuck.

The method of determining the presence and location of leaks in a pipeline in accordance with the invention is to insert the leak location device into the flow of the fluid through a standard fitting and retrieve it from that flow at some station downstream also through a standard fitting.

The device can travel unlimited distance inside a pipe without significantly disturbing the pipe wall. The present invention is a small device, similar in size to a tennis ball and possibly smaller, that travels along with the fluid flow and is completely autonomous. The device has soft spongy outer walls to minimize material dislodged from the walls on impact. It is close to neutral buoyancy. After insertion into the flow through a standard fitting it is swept along by the fluid flow listening for leaks until it is eventually caught and withdrawn from the pipe. The information is recorded during its travels and when downloaded into a computer it displays the presence of any leaks and gives their location.

The device will be referred to as the Leakage Location Pill, or just the Pill. The Leakage Location Pill is autonomous, having no umbilical cable. Being close to neutrally buoyant it travels with the flow of fluid. The Pill has soft, squashable outer walls that ensure that any impact with the pipe wall is gentle so that little if any material is knocked off the internal wall of the pipe and that such impact generates very little acoustic noise. The order of softness is similar to that provided by ten millimetres or more of soft open cell

foam. The Pill contains a hydrophone to listen for leak noise. The data generated by the hydrophone is stored on-board in electronic memory.

The System also includes means to monitor the position of the Pill as it travels along the pipeline. In one embodiment, the Pill also has within it a very low-frequency electromagnetic (EM) continuous detector – occasional transmitter (CDOT). At the start, at the end and at other prescribed points along the pipe are placed low-frequency EM continuous transmitter – continuous detectors (CTCD) whose transmitted signals can be detected inside a pipe, even when the pipe is metallic. When the Pill passes beneath such a surface CTCD it detects the EM signal and records the time at which this occurs. Having detected the signal transmitted from the surface, the CDOT emits a brief signal that is detected by the surface receiver which then gives a display of the fact that the Pill has reached that point. The Pill is captured at some predetermined location downstream through a standard fitting and withdrawn from the pipe. The data is downloaded into a computer and a display shows the presence of any leaks and their location along the pipe that has been traversed. Positioning information on leaks is deduced from a translation of the time information recorded in the Pill into distance location information by interpolation from the time at which the low-frequency EM transmission signals that occur at known locations were received. If the EM signals were not available then the time of entry into the pipe and the time of retrieval would be used to provide distance information although at reduced accuracy.

The proposed method is non-intrusive and does not require any pigging or cleaning operations.

In this proposed method low frequency EM transmitters are deployed at the entry and exit to the pipe and at some convenient intermediate positions along the run that may extend over several kilometres. The more intermediate positions there are the more accurate will be the estimate of position of the leaks. Typical intermediate positions might be at 500m intervals. Advanced Engineering Solutions Ltd manufacture suitable transmitters and receivers. A launch cylinder containing the Leak Location Pill is placed over a valve on a fitting. The diameter of the fitting pipe is smaller than the diameter of the main pipeline and the valve opens to the full bore of that fitting pipe. The valve is initially closed. The valve is opened and a push rod used to drive the Pill through the valve into the flow in the main pipe. The Pill travels along the pipe recording sound levels as it goes. A suitable hydrophone to record the noise is manufactured by Bruel and Kjaer. A dedicated signal processor such as is commonly used in the audio industry will be suitable to process the acoustic data and record it in digital form. The memory requirements are only a few megabytes and a flash memory card or other preferably non-volatile form of memory can be used to store the digital data. The Pill successfully negotiates bends, take-offs as long as they are not flowing, and air release valves. As it passes the EM transmitters the received EM signal is recorded inside the Pill. At the retrieval location a catch device is deployed through a full bore valve on a fitting. As the Pill reaches the retrieval point it is caught and withdrawn through the full bore fitting valve. The valve is closed and the

retrieval tube is removed, together with the Pill. The data download computer is plugged into the Pill and the data is retrieved. The acoustic data and the EM-transmitted data are processed to show the location of leaks along the length of the pipe. When a graphical information system (GIS) is available it can be helpful to display on the GIS system the location of leaks along the pipeline.

The EM unit inside the Pill includes both a receiver and a transmitter. In the event that the Pill should become stuck then, after a fixed period of elapsed time that significantly exceeds the total expected travel time, the EM device begins to transmit 'alarm' information such as a simple pulse or single frequency at regular intervals. A hand held detector above the surface will detect the transmitted information and pin point where the Pill is stuck. If the Pill should free itself then the next time it detects a surface transmitter the alarm will turn off.

A specific embodiment of the invention is now described by way of example with reference to the accompanying figures 1 to 6 that are explanatory sketches of the apparatus in operation.

Figure 1 shows the means of introducing the Leak Location Pill into the pipeline.

Figure 2 shows detail of the Leak Location Pill in one cross-section.

Figure 3 shows an alternative external profile of the Leak Location Pill.

Figure 4 shows the Leak Location Pill travelling along the pipe.

Figure 5 shows the means of retrieving the Leak Location Pill from the pipeline.

In the embodiment shown in figure 1 the pipeline 2 carries the fluid 1 with the direction of flow 8 indicated. An off-take 3 is shown, fitted with a full-bore valve 4 – shown in the closed position. With the valve 4 closed, a spool piece 23 is fitted containing the Pill 5. The spool piece 23 has a push rod 7 passing through a pressure gland 6. Close-by downstream of the off-take 3 is a low frequency EM transmitter 37. The Pill 5 is turned on before being placed in the spool piece 23. The valve 4 is opened fully and the push rod 7 is used to insert the Pill 5 into the main flow of the fluid 1 in the pipe 2. The fluid flow 8 will transport the Pill 5 downstream and as it detects the electro-magnetic field 38 emitted from the low frequency EM transmitter 37 the Pill will record the time at which this signal 38 is detected.

In figure 2 is shown in schematic form the detail of the interior of the Pill. A layer 10 of soft material such as open cell foam surrounds the outer coating 39 of the internal electronics. The foam 10 forms a barrier to ensure that any wall contact is gentle yet does not impede the passage of acoustic waves from the leak generated noise. Inside the Pill is an acoustic hydrophone 9 whose sensitive face penetrates the outer wall 39. Internally there is a module 14 containing signal conditioning, amplifier, analog to digital converter, robust memory and a digital signal processor. There is also a low frequency EM unit 12 containing a receiver/transmitter and with antenna 45 and power supply 13. The units are interconnected by power cables 16 and data cables 15. The hard shell 39 is penetrated by a high pressure connector 40 that incorporates a power switch operated by external intervention through a hole 27 in the outer material. All the internal units 12, 13, 14 are

supported by anti-shock mounts 17. The connector 40 is used to download stored data at the end of a survey and also to provide means to recharge the batteries 13 without needing to open up the Pill.

Leaks from high pressure pipes generate noise in the transported fluid. In figure 4 is shown the Pill 5 in the pipe 2 being pushed along by the fluid 1 in the direction of flow 8. A leak 24 in the wall of the pipe 2 causes acoustic noise 41 to travel upstream and downstream. The noise 41 is detected by the hydrophone 9 on the pill 5 and the magnitude and time are recorded in its internal memory. To improve the accuracy of translation of timing information into positional information along the pipe there can be low frequency EM transmitters 37 placed at fixed points along the pipe as well as at the end points. The location of these fixed points is recorded on the surface computer system 29, figure 6. As the Pill 5 passes these fixed points it detects the low frequency waves 38 and records the time at which these are detected. Having detected the presence of the surface transmitter, the Pill transmits a brief response that in its turn is detected by the surface receiver and an indication given that the Pill has reached this point.

In figure 5 is shown in schematic form how the Pill 5 is retrieved from the pipe 2 at the end of its run. An off-take 48 has on top a full-bore valve 47. Sitting on the valve 47 is a spool piece 44 through which passes an operating rod 46 through a pressure sealing gland 41. The operating rod 46 has at the fluid end a spring steel loop or other deformable frame piece 42 that forms the mouth of a catching net 25. A device 34 for detecting the extra drag on the net when the Pill is in it is mounted on the rod 46. The device 34 is

preferably a strain gauge that can give a simple indication at surface when the Pill 5 is trapped by the net. The cable 35 from the gauge 34 can travel up the centre of the operating rod 46 to avoid compromising the sealing gland 41. In operation as the Pill approaches the retrieval station it detects the low frequency EM waves 38 emitted by the transmitter 37 just upstream of the retrieval station. The time of this occurrence is recorded in the Pill memory. As the Pill passes the retrieval station the net 25 catches it and a signal generated by the gauge 34 is relayed to the surface. A simple meter 43 indicates that the Pill has been caught and the operating rod is withdrawn collapsing the expandable mechanism and pulling the Pill into the space between the valve 47 and the sealing gland 41. The valve 47 is then closed and the spool piece removed to enable the Pill to be completely removed from the water.

After retrieval, the leak noise signal information, the information on the signals received from the low frequency EM transmitters along the way, and the accompanying information on the times at which the signals were received are available to be downloaded via the connector 40. From this information may be estimated firstly the times at which the Pill passed leaks in the pipe work and secondly the location of these leaks.

In a second preferred embodiment of the invention, shown in figure 3, the Pill is not spherical but elongated. Its centre of buoyancy and centre of gravity lie on its long axis but are separated so that the Pill will tend to maintain its long axis vertical. This will cause its lower end to protrude from any recesses in the pipe upper surface, such as air

valves or hydrants, into which it may float, so that the drag of passing fluid will tend to pull it out of the recess and thus avoid its becoming trapped. However, if the Pill should become trapped then, after a period of time that exceeds the expected transit time from launch to retrieve, the Pill will begin to emit an EM alarm at regular intervals. The alarm will be detected by a portable EM detector so that the trapped Pill can be found. If the Pill should subsequently free itself then the alarm will turn off on the next occasion that a surface transmitter is detected. The fact that the alarm has been triggered will be recorded in the internal memory so that the timing information from this run can be rejected.

Figure 1

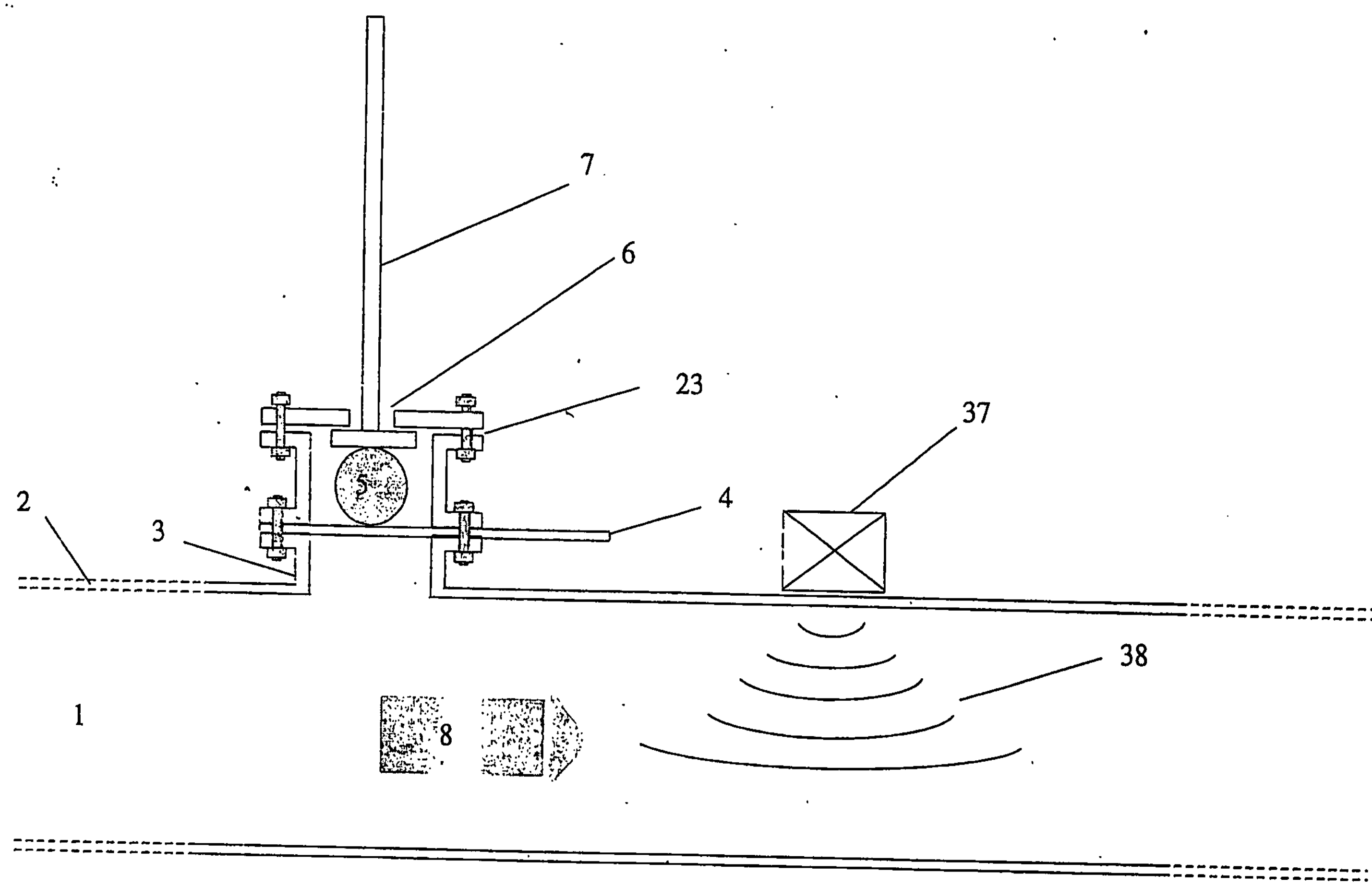

Figure 2

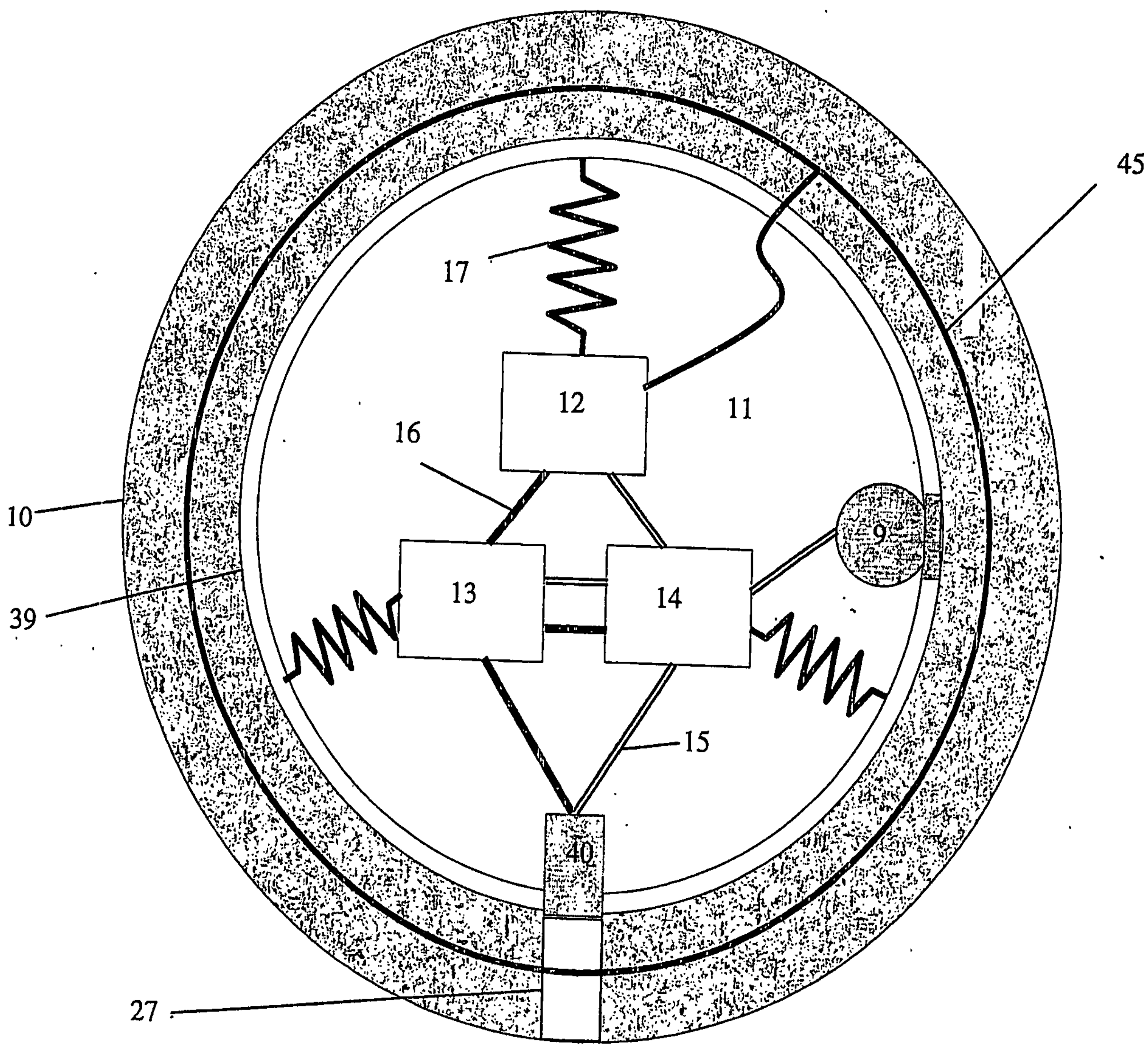

Figure 3

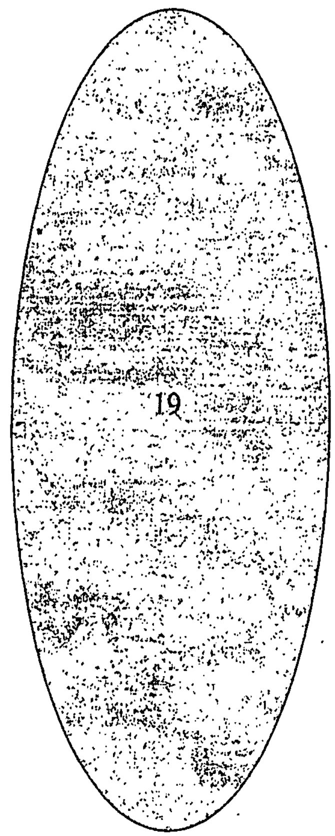

Figure 4

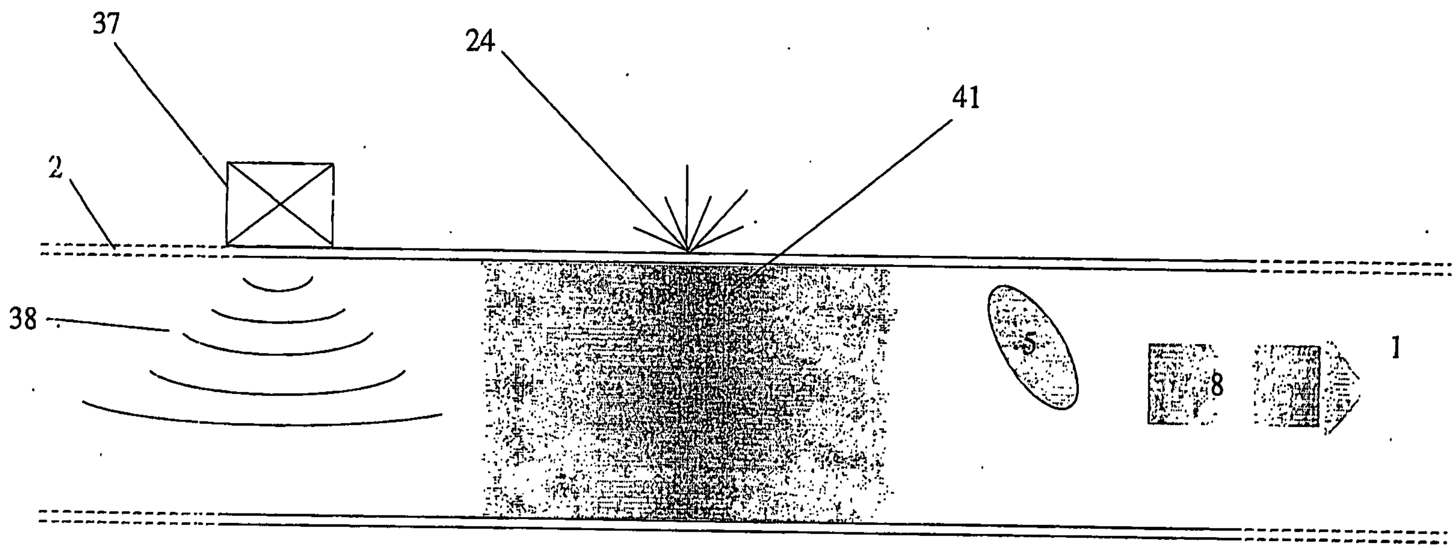

Figure 5